

## Amendment and Response

Applicant: Chistyakov

Serial No.: 10/065,739

Page 2 of 20

Amendments to the Claims:

Please amend claims 1, 4, 5, 6, 8, 12, 16, 19, 21, 25, and 27-30, cancel claims 3 and 18 without prejudice, and add claims 31-39 as follows.

1. (currently amended) A sputtering source comprising:

a cathode assembly that is positioned adjacent to an anode, the cathode assembly including a sputtering target;

an ionization source that generates a weakly-ionized plasma proximate to the anode and the cathode assembly; and

a power supply that generates a voltage pulse that produces an electric field between the anode and the cathode assembly, the electric field that creates a strongly-ionized plasma from the weakly-ionized plasma, an amplitude and a rise time of the voltage pulse being chosen to increase the strongly ionized plasma comprising a volume density of ions in the strongly-ionized plasma that impact the sputtering target which enough to generate sufficient thermal energy in the sputtering target to cause a sputtering yield of the sputtering target to be non-linearly related to a temperature of the sputtering target.

2. (original) The sputtering source of claim 1 wherein the electric field comprises a quasi-static electric field.

3. (cancelled).

4. (currently amended) The sputtering source of claim 3 1 further comprising a gas flow controller exchange means for exchanging that controls a flow of feed gas to the strongly ionized plasma, the additional feed gas allowing additional power to be absorbed by the with a new volume of feed gas while applying the electrical pulse across the new volume of feed gas to generate additional strongly-ionized plasma, comprising a second plurality of ions, the second plurality of the additional power creating additional ions that impacting the surface of the sputtering target, thereby generating additional thermal energy in the sputtering target.

## Amendment and Response

Applicant: Chistyakov

Serial No.: 10/065,277

Page 2 of 20

Amendments to the Claims:

Please amend claims 1, 6, 7, 20, 34, and 40 and add claims 41-48 as follows.

1. (currently amended) A magnetically enhanced sputtering source comprising:
  - a) an anode;
  - b) a cathode assembly that is positioned adjacent to the anode and forming a gap therebetween, the cathode assembly including a sputtering target;
  - c) an ionization source that generates a weakly-ionized plasma proximate to the anode and the cathode assembly;
  - d) a magnet that is positioned to generate a magnetic field proximate to the weakly-ionized plasma, the magnetic field substantially trapping electrons in the weakly-ionized plasma proximate to the sputtering target; and
  - e) a power supply generating a voltage pulse that produces an electric field between the cathode assembly and the anode, across the gap, the electric field an amplitude and a rise time of the voltage pulse being chosen to increase an excitation rate of ground state atoms that are present in the weakly-ionized plasma to create a multi-step ionization process that generates a strongly-ionized plasma from the weakly-ionized plasma, the multi-step ionization process comprising exciting the ground state atoms to generate generating excited atoms, and then in the weakly-ionized plasma and generating secondary electrons from the sputtering target, the secondary electrons ionizing the excited atoms within the weakly-ionized plasma to thereby creating a strongly ionized plasma having create ions that impact a surface of the sputter target material from the sputtering target, to generate sputtering flux.
2. (original) The sputtering source of claim 1 wherein the power supply generates a constant power.

## Amendment and Response

Applicant: Chistyakov

Serial No.: 10/065,277

Page 3 of 20

3. (original) The sputtering source of claim 1 wherein the power supply generates a constant voltage.
4. (original) The sputtering source of claim 1 wherein the electric field comprises a quasi-static electric field.
5. (original) The sputtering source of claim 1 wherein the electric field comprises a pulsed electric field.
6. (currently amended) The sputtering source of claim 1 wherein a the rise time of the voltage pulse electric field is chosen to increase the ionization rate of the excited atoms in the weakly-ionized plasma.
7. (currently amended) The sputtering source of claim 1 wherein the weakly-ionized plasma gas reduces the probability of developing an electrical breakdown condition between the anode and the cathode assembly.
8. (original) The sputtering source of claim 1 wherein the ions in the strongly-ionized plasma impact the surface of the sputtering target in a manner that causes substantially uniform erosion of the sputtering target.
9. (original) The sputtering source of claim 1 wherein the strongly-ionized plasma is substantially uniform proximate to the sputtering target.
10. (original) The sputtering source of claim 1 further comprising a substrate support that is positioned in a path of the sputtering flux.
11. (original) The sputtering source of claim 10 further comprising a temperature controller that controls the temperature of the substrate support.
12. (original) The sputtering source of claim 10 further comprising a bias voltage power supply that applies a bias voltage to a substrate that is positioned on the substrate support.

## Amendment and Response

Applicant: Chistyakov

Serial No.: 10/065,277

Page 4 of 20

13. (original) The sputtering source of claim 1 wherein a volume between the anode and the cathode assembly is chosen to increase the ionization rate of the excited atoms in the weakly-ionized plasma.
14. (original) The sputtering source of claim 1 wherein the ionization source comprises an electrode.
15. (original) The sputtering source of claim 1 wherein the ionization source comprises a DC power supply that generates an electric field proximate to the anode and the cathode assembly.
16. (original) The sputtering source of claim 1 wherein the ionization source comprises an AC power supply that generates an electric field proximate to the anode and the cathode assembly.
17. (original) The sputtering source of claim 1 wherein the ionization source is chosen from the group comprising a UV source, an X-ray source, an electron beam source, and an ion beam source.
18. (original) The sputtering source of claim 1 wherein the magnet comprises an electromagnet.
19. (original) The sputtering source of claim 1 wherein the sputtering target is formed of a material chosen from the group comprising a metallic material, a polymer material, a superconductive material, a magnetic material, a non-magnetic material, a conductive material, a non-conductive material, a composite material, a reactive material, and a refractory material.
20. (currently amended) A method of generating sputtering flux, the method comprising:
  - a) ionizing a feed gas to generate a weakly-ionized plasma proximate to a sputtering target;

## Amendment and Response

Applicant: Chistyakov

Serial No.: 10/065,277

Page 5 of 20

- b) generating a magnetic field proximate to the weakly-ionized plasma, the magnetic field substantially trapping electrons in the weakly-ionized plasma proximate to the sputtering target; and
- c) applying an electric field a voltage pulse to the weakly-ionized plasma, an amplitude and a rise time of the voltage pulse being chosen to increase an excitation rate of ground state atoms that are present in the weakly-ionized plasma to create a multi-step ionization process that generates a strongly-ionized plasma from the weakly-ionized plasma, the multi-step ionization process comprising exciting the ground state atoms to generate excited that excites atoms, and then and that generates secondary electrons from the sputtering target, the secondary electrons ionizing the excited atoms within the weakly-ionized plasma to thereby creating a strongly-ionized plasma having create ions that impact a surface of the sputter target material from the sputtering target, to generate sputtering flux.

21. (original) The method of claim 20 wherein the applying the electric field comprises a applying a quasi-static electric field.

22. (original) The method of claim 20 wherein the applying the electric field comprises applying a substantially uniform electric field.

23. (original) The method of claim 20 wherein the applying the electric field comprises applying an electrical pulse across the weakly-ionized plasma.

24. (original) The method of claim 23 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse that increases an ionization rate of the strongly-ionized plasma.

25. (original) The method of claim 23 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse that reduces a probability of developing an electrical breakdown condition proximate to the sputtering target.

## Amendment and Response

Applicant: Chistyakov

Serial No.: 10/065,277

Page 6 of 20

26. (original) The method of claim 23 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse that causes the strongly-ionized plasma to be substantially uniform in an area adjacent to a surface of the sputtering target.
27. (original) The method of claim 23 wherein the electrical pulse comprises a pulse having a current density that is greater than  $1\text{A/cm}^2$ .
28. (original) The method of claim 23 wherein the electrical pulse comprises a pulse having a pulse width that is greater than 1.0 microseconds.
29. (original) The method of claim 23 wherein the electrical pulse comprises a pulse train having a repetition rate that is substantially between 0.1Hz and 1kHz.
30. (original) The method of claim 20 wherein the ions in the strongly-ionized plasma impact the surface of the sputtering target in a substantially uniform manner.
31. (original) The method of claim 20 wherein the strongly-ionized plasma is substantially uniform proximate to the sputtering target.
32. (original) The method of claim 20 wherein the peak plasma density of the weakly-ionized plasma is less than about  $10^{12}\text{ cm}^{-3}$ .
33. (original) The method of claim 20 wherein the peak plasma density of the strongly-ionized plasma is greater than about  $10^{12}\text{ cm}^{-3}$ .
34. (currently amended) The method of claim 20 further comprising forming a film from the sputtering ~~flat~~ on a surface of a substrate from the material sputtered from the sputtering target.
35. (original) The method of claim 34 further comprising controlling a temperature of the film.
36. (original) The method of claim 34 further comprising applying a bias voltage to the film.

## Amendment and Response

Applicant: Chistyakov

Serial No.: 10/065,277

Page 7 of 20

37. (original) The method of claim 20 wherein the ionizing the feed gas comprises exposing the feed gas to an electric field.
38. (original) The method of claim 20 wherein the ionizing the feed gas comprises exposing the feed gas to an electrode that is adapted to emit electrons.
39. (original) The method of claim 20 wherein the ionizing the feed gas comprises exposing the feed gas to at least one of a UV source, an X-ray source, an electron beam source, and an ion beam source.
40. (currently amended) A magnetically enhanced sputtering source comprising:
  - a) means for ionizing a feed gas to generate a weakly-ionized plasma proximate to a sputtering target;
  - b) means for generating a magnetic field proximate to the weakly-ionized plasma, the magnetic field substantially trapping electrons in the weakly-ionized plasma proximate to the sputtering target; and
  - c) means for applying an electric field a voltage pulse to the weakly-ionized plasma, an amplitude and a rise time of the voltage pulse being chosen to increase an excitation rate of ground state atoms that are present in the weakly-ionized plasma to create a multi-step ionization process that generates a strongly-ionized plasma from the weakly-ionized plasma, the multi-step ionization process comprising exciting the ground state atoms to generate excited that excites atoms, and then and that generates secondary electrons from the sputtering target, the secondary electrons ionizing the excited atoms within the weakly-ionized plasma to thereby creating a strongly-ionized plasma having create ions that impact a surface of the sputter target material from the sputtering target, to generate sputtering flux.
41. (new) The sputtering source of claim 1 wherein the cathode assembly and the anode are positioned so as to form a gap therebetween.

## Amendment and Response

Applicant: Chistyakov

Serial No.: 10/065,277

Page 8 of 20

42. (new) The sputtering source of claim 1 wherein the weakly-ionized plasma is generated from a feed gas that comprises the ground state atoms.
43. (new) The sputtering source of claim 1 wherein the excited atoms within the weakly-ionized plasma are ionized by electrons to create the ions that sputter material from the sputtering target.
44. (new) The sputtering source of claim 1 wherein the rise time of the voltage pulse is approximately between 0.01 and 100V/ $\mu$ sec.
45. (new) The sputtering source of claim 1 wherein the amplitude of the voltage pulse is approximately between 100V and 30kV.
46. (new) The method of claim 20 wherein the weakly-ionized plasma is generated from a feed gas that comprises the ground state atoms.
47. (new) The method of claim 20 wherein a duration of the weakly-ionized plasma is approximately between one microsecond and one hundred seconds.
48. (new) The method of claim 20 wherein the ionizing the excited atoms within the weakly-ionized plasma to create ions that sputter material from the sputtering target comprises ionizing the excited atoms with electrons.
49. (new) The method of claim 20 wherein the rise time of the voltage pulse is approximately between 0.01 and 100V/ $\mu$ sec.
50. (new) The method of claim 20 wherein the amplitude of the voltage pulse is approximately between 100V and 30kV.